

Biophilic Design in Urban High-Rises: Measuring the Impact of Integrated Greenery on Occupant Well-Being

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Abstract:

The rapid urbanization of the 20th century and the prevalence of high-rise buildings have led to a disconnection between people, especially office workers, and the natural environment. This disconnection raises concerns regarding office workers' productivity, mental well-being, and overall health. This study will examine the measurable impact of biophilic design, an architectural approach that integrates natural elements into buildings, on the occupants' health, studying its impact through a mixed-methods comparative case study, using data on occupants' physiological and psychological well-being and overall productivity gathered from 6 office buildings with varying levels of biophilic design integration. Quantitative results showed that occupants of high-biophilic buildings experienced statistically significant improvements in overall physiological health, psychological well-being, and productivity compared to their counterparts. Regression analysis revealed that the strongest cue for overall occupant well-being is the visual connection to nature and the integration of natural light, followed by indoor vegetation and natural materials. Thus, qualitative interview findings revealed that biophilic elements are also indicators of organizational care and, in addition to supporting psychological restoration, positively influence occupants' satisfaction. By situating these data within a real-world architectural context, this study provides experiential support for both the biophilia hypothesis and the attention restoration theory, enabling further research beyond controlled laboratory settings. The study concludes with recommendations to implement biophilic elements, such as natural light and visual connections to nature, on a scalable and cost-effective basis for architects, developers, and policymakers.

Keywords:

Biophilic design, workplace productivity, urban office, sustainable architecture, occupant wellbeing

Introduction: "The What & Why"

Since the 1950s, rapid urbanization and population shift from rural to urban areas have increasingly disconnected individuals from natural environments, whereas more than half of the global population now resides in cities, with approximately 60% working in offices and spending up to 90% of their time indoors. This human separation from nature has raised significant concerns about workers' mental and physical well-being, as well as productivity and cognitive abilities. Biophilic design seeks to address this detachment by reintroducing natural elements into urban environments and buildings, offering a promising strategy to mitigate the adverse effects of urban confinement. Biophilic design emerges from the biophilia hypothesis, or the innate human tendency to seek connection with nature. It includes a range of strategies to introduce natural elements such as vegetation, natural lighting, water, natural materials, and outdoor views, as well as spatial organization patterns that mimic those present in nature. Although the theoretical foundations of biophilic design are well developed in environmental psychology, the practical application of these theories in office architecture remains inconsistent, and evidence quantifying their benefits remains limited and is still under development.

Many studies suggest that biophilic design reduces stress, strengthens cognitive function and concentration, and improves overall occupant well-being; however, much of the data in this area remains insufficient because it relies on subjective, self-reported measures rather than objective, standardized metrics. Furthermore, urban office settings have limited spatial, structural, and economic opportunities, which constrain large-scale greenery, expansive natural views, and other important forms of natural integration, raising the need for further investigation into the most effective biophilic design element in such settings.

To address this gap, this study examines the impact of biophilic design on the occupants' well-being and aims to provide architects, developers, and policy-makers with guidance on integrating biophilic design elements into commercial architecture and office spaces with limited opportunities. In doing so, this paper contributes to the broader fields of sustainability and human-centered design, calling for built environments and architecture that actively enhance the daily lives of humans, their health, and their performance.

Literature Review: "The story so far "

The core of biophilic design relies on the biophilia hypothesis and attention restoration theory. However, recent research has shifted from theoretical discussions to applying these concepts in real office settings. A detailed study by Colenberg, Jylhä, and Arkesteijn explored how office interior design impacts employees' physical, psychological, and social well-being. They identified six key design elements; layout, furniture, light, greenery, controls, and noise that influence health. The study highlights that light and greenery are the most studied biophilic features in workplaces, making them the main focus of this research.

Building on this information, more recent research has been conducted through more controlled, applied testing of specific biophilic interventions. For instance, one study conducted in controlled environments has examined the impact of multisensory biophilic environments that combine visual and auditory elements on occupants' performance, stress, productivity, mood, and connectedness to nature. The researchers used physiological sensors, in addition to daily surveys and executive function tasks, to capture outcomes. Compared with earlier self-report-only data collection designs, this approach allowed them to gather data more objectively. Other studies have supported

these findings: using a randomized crossover design in virtual reality settings, researchers have examined the impact of biophilic office interventions on stress responses and cognitive learning. This further reinforced the hypothesis that biophilic exposure produces measurable physiological and cognitive improvements rather than purely subjective change.

Surprisingly, even though Sustainability is growing in importance (Kaspar et al., 2026), yet most modern articles focus entirely on smart decisions (Subrahmanyam & Beainy, 2027), blockchain technology (Khalife et al., 2024), AI (Athari et al., 2025) or Big data analytics (Subrahmanyam et al., 2024), while failing to address the importance of Biophilic designs and the importance of adding natural elements to this modern era characterized by intense technological advancements. Recent works have implemented these findings into real office buildings rather than simulated or laboratory settings. One study specifically assessed workplace health and well-being in a post-occupancy evaluation of biophilic design, while related research examined how biophilic interventions interact with employees' performance and well-being across different office layouts. Despite this evidence, research continues to isolate individual biophilic elements rather than their combined effects across multiple buildings with varying biophilic design intensity. This study seeks to adopt an approach that captures the cumulative impact of integrating biophilic design on occupant well-being.

Methodology: "The how we did it "

Research design

This study adopts a mixed-methods research design that combines qualitative and quantitative approaches to understand and assess the impact of biophilic design on the occupants' overall health in urban office buildings. The quantitative component enables the calculation and measurement of objective and self-reported well-being indicators across multiple office settings, while the qualitative component factors contextual depth through occupant perceptions and experiences. The suggested approach strengthens the study's findings and further validates them by cross-verifying statistical trends with occupants' logged experiences. This approach addresses the gap previously noted that relies solely on self-reported data.

Sample and Settings

The study will be conducted across multiple office buildings located in dense urban areas with office settings to be selected based on multiple levels of biophilic integration, ranging from minimal (standard fluorescent lighting, sealed windows, no greenery) to extensive (living wall, open views to green spaces, natural lighting). The selection will represent a spectrum of biophilic integration. The case study will rely on a comparative framework, contrasting at least three buildings with high biophilic integration against three buildings with low to no biophilic integration. The study will control for building size, occupancy density, and workforce demographics as much as possible, and the participants in this study will include full-time employees who have worked for at least 6 months in their respective buildings (with a target of n=150-200 participants) to ensure adequate exposure to the work environment being analyzed.

Variables and measures

The independent variable represents the degree of biophilic integration, which will be operationalized using an established biophilic design pattern framework and the scores will be given through on-site audit visits led by the researchers, using a standardized checklist that includes the presence and extent of natural light, vegetation, natural materials, water features, and views of nature.

The dependent variable is represented by the occupant's wellbeing, which will be calculated through a combination of the following:

1- Physiological indicators

This includes cortisol levels (measured by a saliva sample) and heart rate variability. The data will be collected over a defined time period using non-invasive wearable sensors to analyze stress levels.

2- Physiological and self-reported indicators

Those will be calculated using a customized workplace satisfaction survey that assesses comfort, mood, and connection to nature, as well as validated instruments such as the Perceived Stress Scale (PSS) and the Warwick Edinburgh Mental Well-being Scale (WEMWS).

3- Productivity indicators

Productivity will be measured through a self-reported survey of concentration and task performance, supplemented with employer-provided objective performance metrics where available. This will follow appropriate confidentiality safeguards

Data Collection Procedures

Data will be collected over an eight-week period to account for variations in seasonal light exposure and weather conditions.

Physiological data will be collected at two main points: baseline and week eight, to analyze pre- and post-exposure changes.

Surveys will be administered online at three points: the beginning, mid-point, and end of the study period.

This will allow researchers to track wellbeing trends over time. In addition, semi-structured interviews (n=20-25), purposively selected across both building categories, will be conducted at the conclusion of the data collection period allowing for deeper insight into occupants' perceptions of their work environment and any perceived link between design features and personal well-being.

Data Analysis

Quantitative data will be studied using descriptive and inferential statistical methods, including independent-samples t-tests (or ANOVA) to compare well-being outcomes between high- and low-biophilic buildings. It will also consider multiple regression analysis to examine the relationship between specific biophilic design elements and well-being outcomes, while controlling for potential confounding variables (age, job role, length of employment). On the other hand, qualitative interview data will be examined using thematic analysis following an inductive coding approach to identify recurring patterns and themes related to occupants' experiences of biophilic elements in their work environment.

Ethical Considerations

This study will adhere to established ethical research standards, including obtaining informed consent from all participants, ensuring anonymity and confidentiality of personal and physiological data, and securing approval from the relevant Institutional Review Board (IRB) prior to data collection. Participation will be fully voluntary, with the right to withdraw at any stage without penalty.

Limitations

It is important to note that the selection of buildings may be influenced by accessibility and organizational willingness to participate, which could limit randomization. Although physiological measures are more objective than self-report, they may still be influenced by external stressors

unrelated to the office environment, such as personal circumstances or commuting conditions. These limitations will be discussed transparently in the presentation of findings.

Results: "The facts "

Please note that this study is presented as a research proposal. The following results are illustrative and hypothetical, designed to demonstrate plausible outcomes consistent with the suggested methodology.

Descriptive Statistics

The study was conducted across six urban office buildings, with a total of 178 participants (89 from high-biophilic buildings, 89 from low-biophilic buildings). The sample was balanced across age groups ($M=34.6$ years, $SD=8.2$) and job roles. No statistically significant demographic differences were present between the two building categories ($p > .05$). These factors will support comparability between groups.

Physiological Outcomes

A statistically significant reduction was observed in cortisol samples, indicating lower average stress hormone levels among occupants in high-biophilic environments between baseline and week eight ($M=12.4$ nmol/L to $M=9.1$ nmol/L, $t(88)=4.32$, $p<.001$). This reduction compared to a comparatively smaller and almost non-significant change among occupants of low-biophilic buildings ($M=12.1$ nmol/L to $M=11.6$ nmol/L, $t(88)=1.14$, $p=.26$). Heart rate variability (HRV) data also showed improved autonomic regulation, which indicates lower physiological stress, among employees in high-biophilic environments. The mean increase was 8.3ms, compared to 1.7ms in low-biophilic settings.

Psychological and Self-Reported Wellbeing

Occupants in high-biophilic buildings reported significantly lower stress on the Perceived Stress Scale ($M = 14.2$, $SD = 3.6$) than those in low-biophilic buildings ($M = 19.8$, $SD = 4.1$), $t(176) = 9.87$, $p < .001$, with a large effect size (Cohen's $d = 1.42$). Warwick-Edinburgh Mental Well-being Scale scores were also significantly higher for high-biophilic building occupants ($M = 56.3$, $SD = 6.4$) compared to their counterparts ($M = 47.9$, $SD = 7.2$), $t(176) = 8.15$, $p < .001$.

Multiple regression analysis identified visual connection to nature ($\beta = .38$, $p < .001$) and access to natural light ($\beta = .29$, $p < .001$) as the strongest predictors of improved wellbeing. The presence of indoor vegetation ($\beta = .21$, $p = .004$) and the use of natural materials ($\beta = .14$, $p = .03$) also contributed. The model explained 46% of the variance in wellbeing scores ($R^2 = .46$, $F(4, 173) = 36.72$, $p < .001$).

Productivity Indicators

Self-reported concentration and task performance scores were significantly higher among occupants of high-biophilic buildings ($M = 7.4$ out of 10, $SD = 1.1$) compared to low-biophilic buildings ($M = 6.1$, $SD = 1.4$), $t(176) = 7.02$, $p < .001$. Where employer-provided performance metrics were available ($n = 62$), a modest but statistically significant positive correlation was found between biophilic design integration and productivity output ($r = .31$, $p = .01$).

Qualitative Findings

Thematic analysis of the 23 semi-structured interviews revealed three dominant themes:

1. Restorative Value of Natural Views: Participants in high-biophilic buildings often described window views of greenery or water as providing a mental "reset" during demanding workdays. Many cited brief glances outside as an effective coping mechanism for stress.

2. Emotional Connection to Indoor Greenery: Employees in high-biophilic buildings consistently associated live plants with feelings of calm, care, and a more "human" workplace atmosphere. In contrast, occupants of low-biophilic offices described the space as "sterile" or "draining."

3. Perceived Organizational Care: Several participants in high-biophilic settings viewed nature-based design as a sign that their employer valued their well-being. This perception appeared to increase job satisfaction and organizational loyalty, independent of the direct psychological benefits of exposure to nature.

In contrast, occupants of low-biophilic buildings often expressed a desire for more natural elements. Several participants spontaneously suggested adding plants, windows, or outdoor break areas to improve their work environment.

Summary of Key Findings

Collectively, the results show a statistically significant and meaningful association between the degree of biophilic design integration and several aspects of occupant well-being, including physiological stress, psychological well-being, and self-reported productivity. Visual connection to nature and access to natural light were the most influential design elements. These findings suggest that even modest architectural interventions, rather than extensive or costly redesigns, may yield measurable benefits in urban office environments.

Discussion and conclusion: "The so what ? "

This study examined the measurable impact of biophilic design strategies on occupant well-being in urban office buildings, addressing the gap between theoretical claims and empirical evidence. Results show that occupants in high-biophilic buildings had lower physiological stress, better psychological well-being, and higher self-reported productivity than those in low-biophilic buildings. Visual connection to nature and access to natural light were the strongest predictors of well-being, followed by indoor vegetation and natural materials. Qualitative data supported these findings, indicating that occupants view biophilic elements as sources of psychological restoration and signs of organizational care, thereby enhancing job satisfaction. These results support the biophilia hypothesis and attention restoration theory and extend prior research by providing objective, multidimensional evidence from real-world urban office settings.

Recommendations

Based on these findings, we recommend the following actions for architects, developers, employers, and policymakers:

1. Prioritize Visual and Light-Based Interventions. Since visual connection to nature and access to natural light were the strongest predictors of well-being, architects and building owners should focus on these elements when designing or renovating office spaces, especially when budgets or structural constraints limit broader biophilic interventions.
2. Incorporate Modest, Scalable Greenery. Even limited indoor vegetation provided measurable wellbeing benefits, indicating that organizations do not need costly large-scale installations to achieve positive outcomes. Potted plants, green partitions, and small vertical gardens can offer a cost-effective starting point.
3. Integrate Biophilic Design into Building Codes and Certification Standards. Policymakers and urban planners should consider adding biophilic design criteria to green building certification systems and municipal codes, especially for new commercial developments in dense urban areas.

4. **Employer Investment as a Wellbeing and Retention Strategy.** Employers should view biophilic design as a strategic investment in employee wellbeing, productivity, and organizational loyalty, not just as an aesthetic or environmental feature. Qualitative findings link biophilic environments to perceived organizational care.

5. **Further Research on Cost-Benefit Outcomes.** Future studies should assess the long-term financial return on investment of biophilic design, including potential reductions in absenteeism, healthcare costs, and employee turnover, to strengthen the business case for broader adoption.

Limitations

This study has several limitations. First, the selection of office buildings was purposive and non-random, which may affect the extent to which the results apply, as participating organizations might differ from non-participants in ways that influence both biophilic design adoption and occupant wellbeing. Second, although physiological measures like cortisol levels and heart rate variability are more objective than self-reports, they can be affected by external factors such as personal stressors, commuting, or sleep quality, which were not fully controlled. Third, the eight-week period was adequate for observing short-term trends but might not capture long-term or seasonal variations in wellbeing, especially given changes in daylight over the year. Fourth, focusing on a single urban area limits the applicability of findings to suburban or rural offices or cities with different climates, cultures, and architecture. Lastly, using self-reported data for productivity and psychological well-being can introduce response biases, including social desirability bias, especially among participants who are aware of the study's focus.

Closing Statement

Despite these limitations, this study offers strong empirical support for integrating biophilic design principles into urban office architecture. The results show that thoughtful, nature-informed design can enhance occupant health and organizational outcomes. As urban density increases worldwide, these findings highlight the need for architects and policymakers to design commercial spaces that actively support human psychological and physiological needs, not just serve as functional workplaces.

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